TNO Institute for Human Factors IZF

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TNO-report TNO-TM 1994 B-10

J.H. Kerstholt
A.R. Pieters

A COMPARISON OF DECISION MAKING BEHAVIOUR IN A STATIC AND A DYNAMIC TASK ENVIRONMENT AS A FUNCTION OF TIME PRESSURE

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Korte samenvatting van:
Een vergelijking van beslisgedrag in een statische en een dynamische taakomgeving als functie van tijdsdruk
Drs. J.H. Kerstholt en drs. A.R. Pieters
10 juni 1994, Rapport TNO-TM 1994 B-10
TNO Technische Menskunde[1], Soesterberg

MANAGEMENT UITTREKSEL

Bij het onderzoek naar beslissen wordt de laatste jaren meer aandacht besteed aan de invloed van het tijdsverloop waarbinnen een beslissing moet worden genomen. In tegenstelling tot het beslissen in statische taken, waarin op grond van de beschikbare informatie éénmaal een beslissing moet worden genomen, kan in een dynamische taak een foutieve actie worden gecorrigeerd op grond van continue feedback over de algemene toestand van het systeem. Daarom kan verwacht worden dat de uiteindelijke prestaties, in termen van uitkomsten, beter zijn in een dynamische dan in een statische omgeving. Uit voorgaand onderzoek blijkt dat beslissers hun mentale activiteiten aanpassen aan de eisen die door de beslisomgeving worden gesteld. Aangezien een dynamische omgeving de mogelijkheid biedt tot het corrigeren van foutieve acties, dit in tegenstelling tot een statische taak, werd verwacht dat de cognitieve prestaties slechter zouden zijn in een dynamische taakomgeving, ervan uitgaande dat mensen accuraat willen presteren maar met zo weinig mogelijk mentale energie. Voorts werd verondersteld dat de voordelen van een dynamische taakomgeving zouden verminderen als de tijdsdruk toenam, en tevens werd voorspeld dat zowel de uitkomsten als de cognitieve processen in dynamische en statische taken meer overeen zouden komen naarmate de tijdsdruk toenam.
In een experiment werden twee versies van dezelfde diagnosetaak gebruikt: een dynamische en een statische versie. In deze taak moesten de proefpersonen de oorzaak van de conditieverslechtering van een atleet diagnostiseren en indien dit nodig was, een behandeling geven. In de dynamische taakconditie beslisten de proefpersonen real-time, en zij zagen op een beeldscherm een grafiek die het conditieniveau van de atleet weergaf. In de statische taakconditie beschikten de proefpersonen niet over deze informatie en hun taak was om één enkele diagnose te geven binnen een bepaalde tijdslimiet.
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Report No.: TNO-TM 1994 B-10

Title: A comparison of decision making behaviour in a static and a dynamic task environment as a function of time pressure

Authors: Drs. J.H. Kerstholt and Drs. A.R. Pieters

Institute: TNO Human Factors Research Institute
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SUMMARY

Decision making research shows an increasing interest for time-dependent decisions. In contrast with decision making in static tasks, where, based on the available information, only one decision needs to be made, dynamic environments offer the possibility to adjust incorrect decisions through continuous feedback on the overall system state. It is therefore to be expected that the outcome performance will be better in a dynamic than in a static task environment. Previous research indicates that decision makers adjust their mental activities to the demands of the decision environment. Since dynamic environments offer the possibility for corrective actions, in contrast to static environments, it was predicted that cognitive performance would be worse in a dynamic task, on the assumption that people want to make accurate decisions with minimal mental effort. Furthermore, as it was assumed that the advantages of dynamic environments would reduce as time pressure increased, we predicted that both outcomes and cognitive performance would be more equal in dynamic and static tasks as time pressure increased.

In an experiment two versions of a similar diagnosis task were used: a static and a dynamic one. Subjects were required to diagnose the cause of a decreased fitness level of an athlete, and to apply treatments whenever necessary. In the dynamic task version subjects decided in real time, and they saw a graph on a computer screen that represented the athlete's fitness level. In the static task version, subjects did not get this information and their task was to make one diagnosis per trial.

The results show that outcome performance was higher in the dynamic than in the static task version. Cognitive performance was worse in the dynamic task version as compared with the static one: subjects worked at a slower rate and they integrated the information less well. Outcome performance was equal for the dynamic and the static task version under a high level of time pressure. Cognitive performance improved under time pressure: subjects speeded up information processing and integrated the information more accurately.

The results show that decision makers not only work harder when task demands increase, for example under time pressure, but they also work more carelessly when it is less essential to make an optimal decision, such as when it is possible to adjust incorrect actions.

Rap.nr. TNO-TM 1994 B-10

TNO Technische Menskunde[1]
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Een vergelijking van beslisgedrag in een statische en een dynamische taakomgeving als functie van tijdsdruk

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SAMENVATTING

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1 INTRODUCTION

Over the past decade a growing interest can be observed for dynamic decision making. Experimental simulations have been developed for a wide area of task domains, such as fire fighting (Brehmer, 1992), economics (Sterman, 1989), microburst forecasting (Lusk & Hammond, 1991) and medical care (Kleinmuntz & Thomas, 1987). However, even though these studies have provided some insight into decision making in dynamic tasks, the broad differences in tasks, complexity, dependent variables and subjects' prior knowledge make it difficult to draw conclusions on dynamic decision making in general, and on how decision making in dynamic situations differs from decision making in the more frequently used static tasks. The present study aims at bridging this gap by relating decision making behaviour in a dynamic task to decision making behaviour in an otherwise identical static task.

1.1 Characteristics of dynamic situations

Compared with static tasks, the major characteristic of a dynamic situation is its change over time, which occurs both autonomously and as a result of actions taken by a decision maker. Of importance to dynamic decision making is therefore the possibility to affect the development of the system over time. Most researchers also included the need to make several, interdependent, decisions in their definition of dynamic decision making (Brehmer, 1992; Edwards, 1962). In the present study this interdependence of decisions is minimized, in order to enhance experimental control. With dependent trials it would be more difficult to measure systematically the cognitive processes underlying the decisions.
In dynamic tasks the decision maker has the possibility to use feedback as an input for further actions (Hogarth, 1981). The advantage of this possibility is that adjustments can be made whenever deviations are observed from a desired outcome, as the decision maker can make small steps at a time (or in other words, work incrementally). A necessary condition is, of course, that the decision maker receives continuous feedback on at least overall system performance. As a result of this possibility to correct errors, however, dynamic decision making was found to be rather insensitive to deviations from a normative strategy (Rapoport, 1975). Thus, even if single steps deviate from optimal performance, the overall performance can be rather accurate as decision makers can continuously adjust their course of action to the desired outcome. In general, we therefore predict that outcome performance will be superior in dynamic tasks as compared with static tasks.

In simple situations, where actions cannot result in disastrous consequences, such a prediction seems to be rather trivial: people may endlessly try different actions in order to increase system performance to some desired level. However, inherent to dynamic decision making is a notion of time, which may change into feelings of time pressure when the probability of undesirable consequences

gradually increases over time. Even though the concept of time seems to be very basic to dynamic decision making, only a few studies have addressed this topic. Rather, most studies investigated decision making in complex situations without time pressure (for example Brehmer, 1992; Sterman, 1989). An important conclusion from this line of research is that deviations from optimal behaviour largely result from misperceptions of feedback, especially when this feedback is delayed. However, because of the confounding between complexity and dynamics it remains to be investigated whether such a result is due to an inadequacy to deal with process dynamics or to the absence of an accurate mental model of the process, and consequently an inability to predict system behaviour. In other words, many results on dynamic decision making refer to a combination of task complexity and task dynamics (Dörner, 1987; Funke, 1991). In the present study we tried to disentangle these effects by focusing on the effect of process dynamics only, excluding the effect of knowledge as an explanation for the experimental findings.

1.2 Time pressure

Inherent to dynamic decision making is the consideration of time, and when time is very limited or when time is not dealt with efficiently, the decisions have to made under time pressure. Studies on time pressure mainly concerned static tasks where time pressure is imposed on people by means of deadlines (see for a review of time pressure effects on decision making behaviour in static tasks Edland & Svenson, 1993). These studies indicated that time pressured subjects placed greater weight on important attributes (Svenson & Edland, 1987), used noncompensatory strategies more often (Zakay, 1985) and increased processing speed (Ben Zur & Breznitz, 1981; Maule & Mackie, 1990; Payne, Bettman & Johnson, 1988). Furthermore, under time pressure the accuracy of the chosen option was reduced (Zakay & Wooler, 1984).

Rather than by external deadlines, time pressure in dynamic situations is induced by the rate of change of the process itself: when a system evolves rapidly towards an undesirable consequence, people will experience time pressure. Theoretically, the possibility to use feedback in dynamic situations extends the behavioral repertoire of the decision maker to deal with time pressure. In a static task, subjects necessarily use a diagnostic strategy: they first request information, this information is integrated, and the best option is the one with the highest overall value. Time pressure may be overcome by, for example, a strategic selection of a subset of the available information. In a dynamic situation, on the other hand, decision makers can also restrict themselves to the application of actions only, and thus totally omit the information search phase, as the effect of the actions can be observed from the overall system state (Kleinmuntz & Thomas, 1987). Previous research indicated, however, that subjects tended to use judgment-oriented strategies in dynamic situations as well, and that time restrictions were not handled by changing to a more action-oriented strategy (Kerstholt, submit-

ted; Kleinmuntz & Thomas, 1987). Still, even though subjects presumably request information first in both static and dynamic task conditions, there is a possibility to correct an erroneous action in the dynamic task condition. By limiting the available time, however, this possibility for correction is reduced, which would imply that static and dynamic tasks will become more equal under time restrictions.

1.3 Adaptive decision making

Recent theoretical considerations stress the adaptive character of decision making behaviour (Smith, Mitchell & Beach, 1982; Payne, Bettman & Johnson, 1993). In general, theories of adaptive decision making assume that people select a strategy that maximizes the net result of a decision process in terms of decision costs and benefits, where costs are defined by variables such as time and effort. Payne, Bettman and Johnson (1988), for example, showed that time pressured subjects selected strategies that saved considerable effort (and time), with only limited reductions in accuracy. As noted above dynamic environments are relatively lenient with regard to deviation from normative behaviour as it is possible to adjust incorrect actions, or in other words, it will *not make much* difference to overall performance when less effort is put into information processing. Thus, on the assumption that subjects consider both effort and accuracy in selecting a decision strategy, we predicted that less effort is invested in decision processes in dynamic tasks than in static tasks.

To summarize, we predict that in a dynamic task the decision outcome will be higher than in static tasks and that subjects invest less effort in a dynamic task than in a static task. However, as the possibilities to correct decisions are reduced when time pressure increases, the task conditions will become more identical, resulting in lower outcomes in the dynamic task (comparable with the static one) and an additional increase in effort in the dynamic task (to overcome both time pressure *and* the reduced advantages of task dynamics).

1.4 Experimental task

In order to investigate these expectations, an experimental task was designed, with a static and dynamic version of an otherwise identical task. In this task subjects were required to diagnose an athlete, who could suffer from several disorders. Subjects could request information on various symptoms that provided an indication for the actual state of the athlete. In contrast with the static task version, the dynamic task version provided subjects with information on the overall fitness level of the athlete, and its course over time, by means of a graph. From the course of this graph it could be deduced whether an action was correct. However, the availability of outcome feedback in the dynamic task version, could also induce differences between the dynamic and the static task

version because of learning effects over time. In order to measure these effects, we distinguished two conditions in the static task version: one in which subjects received feedback on the accuracy of their diagnosis (after each trial it was indicated whether the correct diagnosis had been selected), and one in which this information was not provided.

2 METHOD

2.1 Subjects

Thirty-six subjects, all students at the University of Utrecht, participated in the experiment. They were paid Dfl. 45 and furthermore had a chance of receiving a bonus, which was given to the best performing subject. The task lasted two to two and a half hours.

2.2 The experimental task

Dynamic task version

Subjects were required to imagine that they were the personal attendant of an athlete who was running a race. The fitness level of this athlete was continuously presented to the subjects by means of a graph on a computer screen (see Fig. 1). The fitness level of the athlete could vary between 100 (optimal fitness level) and 0 (the athlete had collapsed).

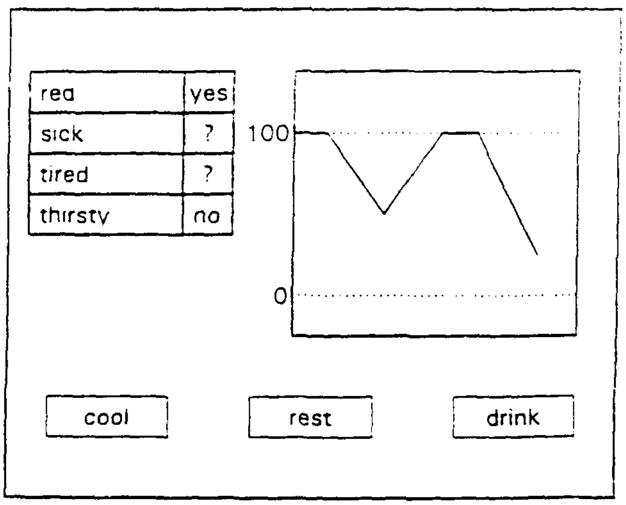

Fig. 1 Example of a computer screen for the dynamic task version, showing the athlete's fitness level, possible symptoms and actions.

A trial always started with a fitness level of 100, but at several points in time the fitness level would decline. A decline could be due to four causes: the athlete could suffer from a temperature problem, from a circulation problem, from a metabolism problem, or the fitness decline was caused by a false alarm. A false alarm meant that the fitness level of the athlete declined without any physiological cause, and as a result it would recover spontaneously at a fitness level of 50. On the other hand, when the decline of the athlete's fitness was caused by either a temperature, a circulation or a metabolism problem, the decline would continue to decrease until a value of 0, assuming that nothing was done by the subject. The a priori probabilities of the various causes were: .1 for a temperature problem, .1 for a circulation problem, .3 for a metabolism problem and .5 for false alarms.

A decline evolved linearly and was always prompted by a change in one parameter, athletes had either a temperature problem, or a circulation problem, or a metabolism problem or the decline was due to a false alarm. Thus, the graph in Fig. 1 shows two successive trials: in the first trial a false alarm occurred (the fitness level spontaneously recovered at a value of 50) and the subject still works on the second trial. It is clear in this second trial, however, that the decline is not caused by a false alarm, because the graph is lower than a fitness level of 50. Thus, a fitness decline provided information on the onset of a possible disturbance (the fitness level started to decline) and over time subjects would learn whether the decline was merely a false alarm (the athlete's fitness level spontaneously recovered) or was caused by a physiological disturbance.

In order to get some insight into the reason for the fitness decline, subjects could request information. The information requests were served by mouse clicks and the response was either "yes" (the athlete had the symptom) or "no" (the athlete did not have the symptom). The symptoms that could be requested were: red colour, feeling sick, tired, and thirsty. The probabilities of the occurrence of a symptom, given a particular cause $p(S_i \mid H_j)$ were as follows (the probability of the symptom, given other causes $[p(S_i \mid -H_j)]$ is put in brackets):

	temperature	circulation	metabolism	false alarm
red colour	0.9 (0.19)	0.1 (0.28)	0.2 (0.29)	0.2 (0.32)
feeling sick	0.2 (0.31)	0.8 (0.24)	0.5 (0.21)	0.1 (0.50)
tired	0.3 (0.52)	0.4 (0.51)	0.6 (0.46)	0.5 (0.49)
thirsty	0.3 (0.43)	0.2 (0.44)	0.8 (0.29)	0.3 (0.54)

In dynamic tasks, decisions are directed towards actions and for that reason subjects needed to give treatments in order to restore the athlete's fitness level from a physiological disturbance. For each problem one specific action was needed: cooling in case of a temperature problem, resting in case of a circulation problem, and drinking in case of a metabolism problem. If the correct treatment was applied, the athlete's fitness would be restored, which could be deduced from a change in the curve from a decreasing fitness level to an increasing one.

Time pressure was manipulated by the rate at which the athlete's fitness declined: the fitness level could decrease from 100 to 0 in respectively 16, 8 or 4 seconds.

Static task version

Exactly the same diagnosis task was used in the static as in the dynamic task version. Subjects could request the same information, and the probabilities of disturbances and false alarms were equal to the dynamic task version. However, in the static task version subjects did not control the athlete in real time. These subjects were told, therefore, that they were working in a first aid post, and that they had to diagnose several athletes within an indicated time constraint. These subjects did not receive any information on the athlete's fitness level (the graph in Fig. 1 was not present). Instead, these subjects had to click with the mouse on a "start" button that would start the trial, indicated by the filling up of a time bar. Thus compared with the dynamic task version, a trial resembled the start of a fitness decline. In the static task version, time was indicated by a time bar, which would fill up in 16, 8 or 4 seconds.

2.3 Procedure

The experiment was divided into two parts: a training session and the actual experiment. In the training session subjects had to learn the relations between combinations of symptoms and the most probable causes. They were given the information on a priori probabilities, on the probabilities of symptoms given the possible causes of the decline, $[p(S_i \mid H_j)]$, and on the probabilities of the symptoms given other possible causes of the decline $[p(S_i \mid -H_j)]$. The information on symptom/hypotheses relations were presented in eight bar-plots. Fig. 2 shows an example of such a plot for one of the symptoms (red colour). Subjects interacted with a computer program that presented them random combinations of symptoms (for example, "not red, not sick, thirsty and tired"). The subjects had to select the most probable cause given the symptoms. After each trial they were given feedback on the accuracy of their diagnosis, including both its correctness with regard to the requested information (according to Bayes' formula) and with regard to the actual cause of the decline. In case of an incorrect diagnosis they were also told which one should have been selected (given the requested information). After each run of 10 trials the subject was given feedback on his or her overall score of the run. The general learning criterion was three successive runs comprising two runs that were 100% correct, with a maximum time for training of two hours.

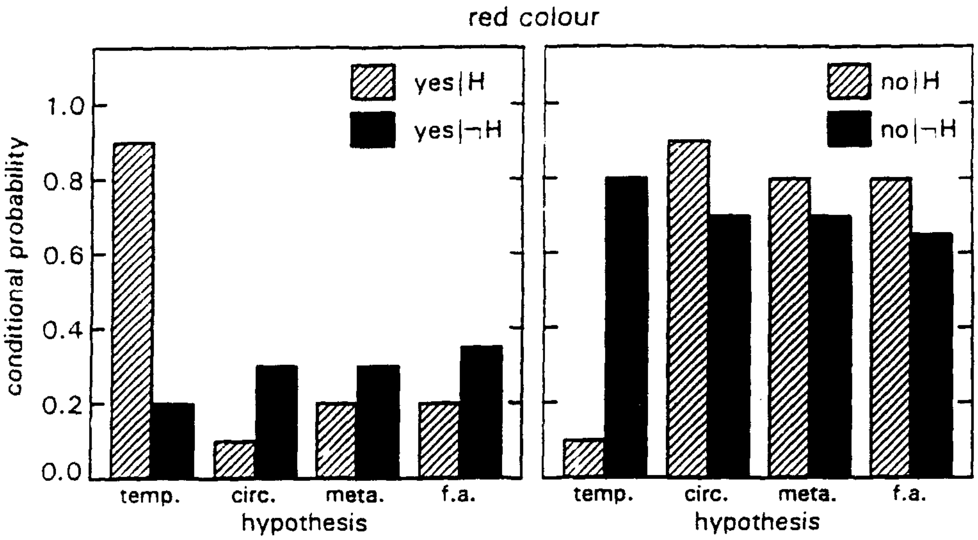

Fig. 2 Information on the relation between symptoms (in this example red colour) and causes, provided to the subjects in the training session.

After learning the relations between symptoms and underlying causes, the subjects continued with the actual experiment in one of the three experimental task conditions, the static task version without feedback, the static task version with feedback and the dynamic task version.
The subjects were informed on the exact probabilities and they were given practice trials for the various time conditions in order to familiarize them with the physical task environment and to let them determine their decision strategy.
In order to motivate subjects to trade-off information requests and risks on athlete collapses in a conscientious manner, money was deducted for information requests, wrong treatments and athlete collapses (or, in case of the static task version, being too late). The subject with the highest overall money level at the end of the experiment received a bonus of Dfl. 50,-.

2.4 Design

Three different task conditions were used: dynamic, static without feedback, and static with feedback. Subjects were randomly assigned to one of these conditions (12 subjects per condition). Time pressure was a within-subjects variable, manipulated by slope (dynamic task) or the filling rate of a time bar (static task), and comprised the values: 16, 8 and 4 seconds. The order of time pressure conditions was balanced across subjects. The subjects were presented with 30 fitness declines in each time pressure condition. In the dynamic task a trial would end after a correct treatment was applied, and the fitness level consequently increased to a value of 100, or when the athlete collapsed (a fitness level

of 0). In the static task a trial would end when either a diagnosis was made or when the time limit was reached.

Dependent variables

1 **Outcome performance** is the mean amount of money at the end of each time pressure condition. This variable indicates how well subjects traded-off the costs of information and actions.
2 **Effort** is defined by the combination of *speed* and *accuracy* of the information integration process. After requesting information, an integration process takes place in order to deduce the diagnosis. The time between the last information request and a subsequent action is taken as an indication for processing speed. Accuracy relates to the interpretation of the requested information. To that extent we calculated per trial the a posteriori probability of the four diagnoses given the requested information. Accuracy is defined by the difference between the highest a posteriori probability (the best hypothesis given the requested information) and the a posteriori probability of the chosen diagnosis. More effort is invested in the task as information processing speeds up, while maintaining or increasing accuracy, or when accuracy increases, while maintaining the same speed.
3 **Process variables** are the *amount* of requested information and the *kind* of requested information. In order to infer the efficiency of the information requests, we calculated the uncertainty reduction for each symptom that was requested first after a fitness decline. The following formula was used (H_i= hypotheses, S_j=symptoms) (Dretske, 1981):

$$\sum_{i=1}^{4} [(H_i \mid S_j) * \log_2 \left(\frac{1}{(H_i \mid S_j)}\right)]$$

The weighted sum of uncertainties when the symptom would be present or absent provides the overall value per symptom. Subtracting this value from the uncertainty one would have without symptom knowledge (1.7 bits), gives the amount of uncertainty reduction gained by knowing the outcome of each of the symptoms. The uncertainty reduction was .2 bits for "sick", .15 bits for "red", .12 bits for "thirst" and .02 bits for "tired". Thus, from an efficiency point of view, the best (first) symptom to know would be the symptom "sick".

3 RESULTS

3.1 Training

Not all subjects were able to learn the relationships between symptoms and underlying causes up to the criterion within the time constraint of 2 hours. One

subject in condition 1 and four subjects in conditions 2 and 3 each did not meet the criterion of two times 100% correct in three successive trials. However, as far as the number of trials and the end scores are concerned there is no significant difference between the subjects in each experimental condition [mean number of trials in the three conditions were 237, 202 and 192 trials respectively, $F(2,33) < 1$, and the mean percentages correct in the last trial in each experimental condition were 89%, 93% and 86% respectively, $F(2,33) = 1.12$, $p > .3$]. Furthermore, as the results did not change with the subjects who did not meet the learning criterion excluded, we present the data for the total group of subjects.

3.2 Experimental data

For all analyses that follow no effects were found for the two conditions of the static task version, with and without feedback on the accuracy of the diagnosis, and for that reason we collapsed the data across both conditions.
As the subjects in the dynamic task condition could observe the development of the athlete's fitness level over time, they could wait in order to observe whether the fitness level would spontaneously recover (in the case of false alarms). In order to make the static and the dynamic task conditions maximally comparable, we only considered the trials concerning physiological causes.

Outcome performance

Subjects in the dynamic condition made more money than subjects in the static condition [$F(1,34) = 10.47$, $p < .005$, see Fig. 3].

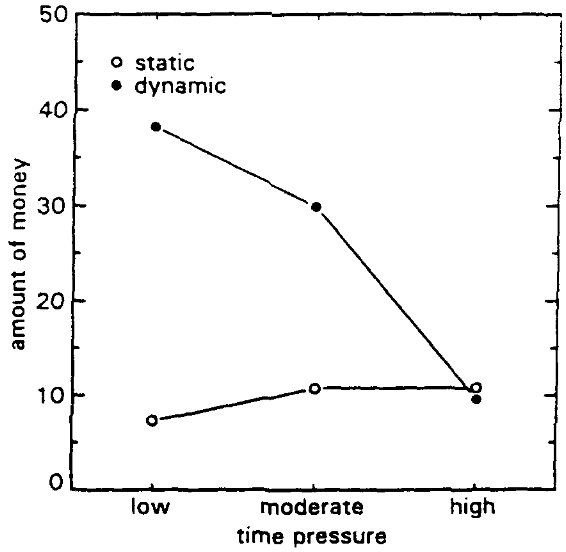

Fig. 3 Amount of money (in guilders) for the dynamic and the static task condition at the end of each time pressure condition (low, moderate and high).

The amount of money earned across time pressure conditions interacted with the task version [$F(2,68)=6.44$, $p<.005$]. Outcome performance remained constant across time pressure conditions for the static task version [$F(2,46)<1$], but decreased over time pressure conditions for the dynamic task version [$F(2,22)=5.57$, $p<.05$]. In the highest time pressure condition there is no difference between the mean outcome of the static task version and the dynamic task version [$F(1,34)<1$].

Processing speed

In the static task version, subjects were faster than in the dynamic task version [$F(1,29)=159.69$, $p<.0001$, see Fig. 4]. Furthermore, subjects were faster when time pressure increased [$F(2,58)=58.67$, $p<.0001$]. The effect of time pressure on processing speed interacted with the task version [$F(2,58)=19.05$, $p<.0001$]: the decrease in processing time is larger for the dynamic than for the static task version.

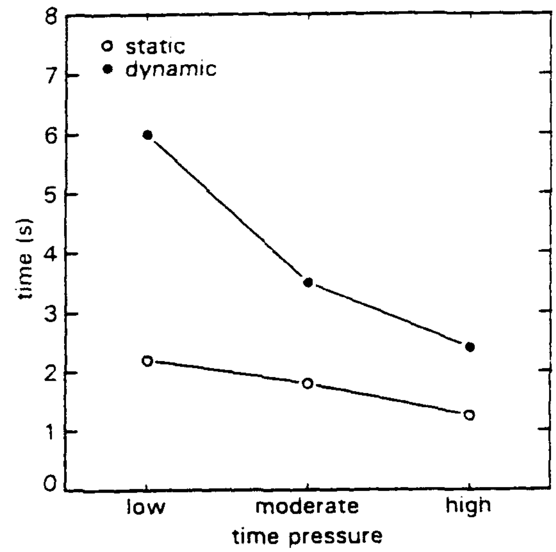

Fig. 4 Time span between last information request and succeeding action for the dynamic and the static task version and for each time pressure condition (low, moderate and high).

Accuracy

Subjects in the static task version integrated the requested information more accurately than subjects in the dynamic task version [$F(1,34)=94.90$, $p<.0001$, see Fig. 5]. When time pressure increased the information was more accurately integrated [$F(2,68)=4.34$], and this effect is the same for the static and the dynamic task version [$F(2,68)<1$].

Thus, even though subjects in the dynamic task conditions took more time for information integration they made less accurate diagnoses.

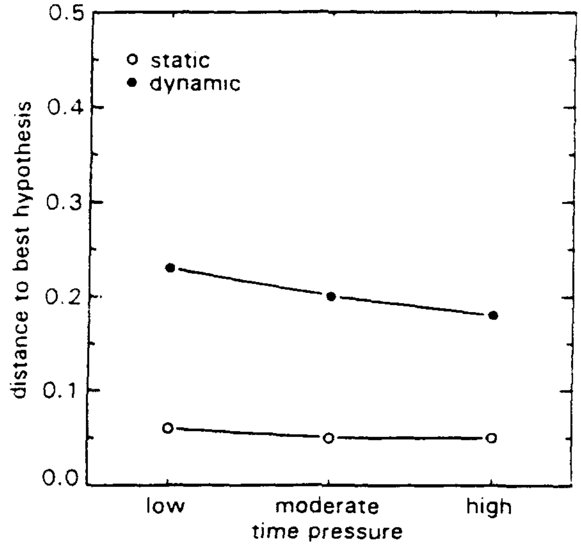

Fig. 5 Accuracy of the information integration process (probability of the best hypothesis given the requested information minus the probability of the chosen option given the requested information) for the dynamic and the static task version and for each time pressure (low, moderate and high).

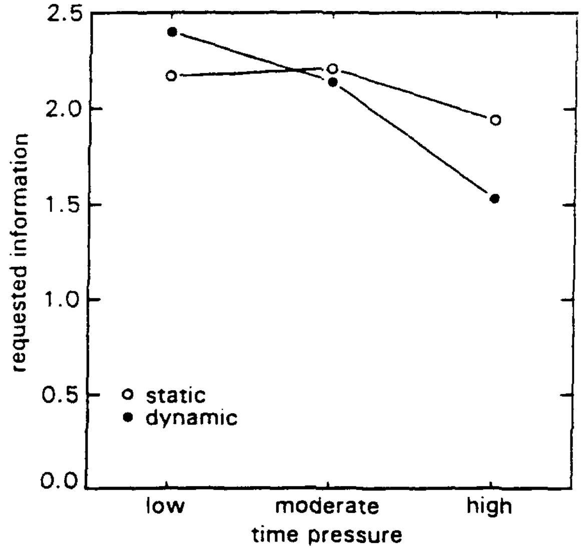

Fig. 6 Mean number of information requests in the dynamic and the static task version and for each time pressure condition (low, moderate and high).

Number of information requests

The amount of information requested did not differ across task versions [$F(1,34) < 1$, see Fig. 6]. When time pressure increased less information was requested

[$F(2,68)=3.34$, $p<.05$], and this effect was the same for the static and for the dynamic task version [$F(2,68)=1.03$, $p>.3$].

Kind of requested information

Analyses over the first information requests showed that the symptoms were not equally often requested [$F(3,99)=5.36$, $p<.005$, see Table I]. Subjects mostly requested the symptom "sick", followed by the symptoms "thirst", "red" and "tired". This effect was the same for the static and the dynamic task version [$F(3,95)=1.70$, $p>.1$]. Therefore, subjects correctly requested the symptom "sick" most often, as this knowledge would reduce most uncertainty.

Table I Proportion of each symptom (red, sick, tired and thirst) that was first requested after a fitness decline for the dynamic and the static task version, and for each time pressure condition (low, moderate and high).

	static			dynamic		
	low	moderate	high	low	moderate	high
red	0.23	0.24	0.16	0.09	0.09	0.10
sick	0.52	0.46	0.60	0.36	0.29	0.17
tired	0.01	0.03	0.02	0.03	0.07	0.14
thirst	0.17	0.20	0.16	0.31	0.25	0.33

However, an interaction was found between kind of requested information, time pressure and task version [$F(6,198)=2.90$, $p=.01$]. Under the highest level of time pressure subjects in the static condition requested a different kind of information than subjects in the dynamic task version [$F(3,99)=4.48$, $p<.01$]. In the moderate and low time pressure conditions the kind of requested information was the same in both task versions [$F(3,99)<1$] for both time pressure conditions. As can be seen in Table I subjects in the high time pressure condition requested the symptom "sick" less often in the dynamic task version than in the static task version, indicating a less efficient information search strategy as time pressure increased.

4 DISCUSSION

The prediction that subjects would make more money in the dynamic task version, with less effort, was supported by the present findings. Even though subjects in the dynamic task version took more time, they integrated the requested information less accurately as compared with the subjects in the static task version. This indicates the investment of less effort in the dynamic task as

compared with the static task. The higher performance outcome may well be explained by the extra information on the athlete's fitness level, that was only received in the dynamic task version: these subjects could wait and see whether the decline was caused by a false alarm, and they could try another treatment in case the fitness level did not increase as a result of their action.
An important implication of this finding is the need to know the environmental structure for understanding decision processes. Traditionally, decision making behaviour has been related to statistical, normative solutions such as maximalisation of expected utility. Adaptation however, refers to the structure of the environment, rather than to formal normative decision procedures (Anderson, 1990). On incorporating effort as well, decision processes may be adaptive when related to structural features of the environment, even though the outcome deviates from a statistically optimal solution. Such a position emphasizes the importance of the resemblance of structural features of laboratory tasks with the world in which these decision processes were developed. This point has long been advocated by Social Judgment Theory (Brehmer & Joyce, 1988), but has been largely ignored by process tracing studies in general.
The time pressure effects replicated previous findings (Edland & Svenson, 1993; Kerstholt, submitted): as a reaction to time pressure subjects speeded up information processing and integrated the information more accurately. Furthermore, less information was requested as time pressure increased, without affecting the outcome performance, however. Thus, subjects tried to overcome time constraints by increasing effort, and worked both faster and smarter.

As time pressure increased, however, the advantages of the dynamic task version were reduced, and as a result the outcome was the same for both task versions under the highest level of time pressure. We had predicted that the behavioral indices would also be comparable for the dynamic and the static task version under time pressure. However, this prediction was only partially supported. Subjects in the dynamic task version disproportionately speeded up information processing, but the accuracy difference remained constant across time pressure conditions. Thus, it can be concluded that the subjects did put extra effort into the dynamic task when time pressure increased, in order to overcome the decreasing advantages of task dynamics, but only by working faster and not by working smarter.
Yet, if also the information search is considered, it can be concluded that the decision processes become less efficient in the dynamic task version under a high level of time pressure: the subjects in the dynamic task selected less optimal information, compared with the static task version, and with the more lenient time pressure conditions. Note that selecting less discriminating information is an unadaptive reaction, in contrast with, for example, the selection of less information, which would save time.

Thus, the separate effects of task environment and time pressure agree with theoretical notions that incorporate both outcome performance and effort as

factors influencing decision processes: as the environment provided more opportunities for high outcomes, subjects invested less effort into the process, but under time pressure they increased their effort. Payne, Bettman and Johnson (1988) defined effort by elementary information processes (EIP), and calculated for a range of decision strategies both the necessary effort and the expected accuracy. In their study they found that subjects reacted adaptively to different task variations: under time pressure, for example, subjects selected a strategy that saved considerable effort at the expense of only limited accuracy. In our study, subjects did not use another strategy in the static and dynamic task versions and in the various time pressure conditions, but implemented the same strategy in a more or less thorough way (note, that the task environment should also allow for the selection of a broad range of decision strategies). Thus, effort effects may be indicated by either a strategy shift, or by a more or less thorough implementation of the same strategy.

For the combined effect of task version and time pressure, decision making seemed to be less adaptive, however. An explanation for this effect may be that subjects in the dynamic task version experienced more time pressure than the subjects in the static task version, as they could react later to a fitness decline. The result of a waiting period after the onset of a fitness decline, is that information can be received on false alarm trials, but also that more time pressure is created when a decline is caused by a physiological disorder. This explanation implies that decision processes will deteriorate under more restricted time limits than the ones used in the present experiment. Under extremely limited time conditions subjects may begin to feel time stress, resulting in nonadaptive behaviour. Note, however, that there need not be less accurate processing in the dynamic task version than in the static task version under time pressure. Subjects had the same knowledge of symptoms and causes and the same amount of time. Thus, the results may imply that time stress overrules the knowledge subjects have on, for example, symptom information, resulting in more erratic behaviour.

For accurate decision processes, comparable to the static task version, subjects in the dynamic task version had to give up the advantages of the dynamic character of the task. Presumably, subjects in the dynamic task version experienced conflicting goals: the task dynamics required them to wait and to use feedback on the athlete's fitness level, whereas time pressure required them to react immediately to a fitness decline and to process the information as accurately as possible in order to increase the probability of the first diagnosis being correct. This would imply that adaptation breaks down when multiple goals require different behavioral responses. More research is needed to investigate the combined effects of various task and context variables on decision making behaviour, especially when these factors require conflicting responses.

To conclude, the present results show, compared with a static task with low time pressure, adaptive reactions to both a simplifying task factor, a dynamic task environment, and to a complicating task factor, time pressure. Subjects responded to the task dynamics by decreasing effort (slower and less accurate

information processing) and to time pressure by increasing effort (faster and more accurate information processing). Under a high level of time pressure, the outcome became equal in both task versions, and processing speed increased disproportionately in the dynamic task condition. Over time pressure conditions, the difference in processing accuracy between both task versions remained constant, but information search deteriorated in the dynamic task version. Thus, under a high level of time pressure, decision processes were suboptimal for the subjects in the dynamic task condition, suggesting a break down of adaptation when people are faced with multiple, conflicting goals.

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15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTE)

Decision making research shows an increasing interest for time-dependent decisions. In contrast with decision making in static tasks, where, based on the available information, only one decision needs to be made, dynamic environments offer the possibility to adjust incorrect decisions through continuous feedback on the overall system state. It is therefore to be expected that the outcome performance will be better in a dynamic than in a static task environment. Previous research indicates that decision makers adjust their mental activities to the demands of the decision environment. Since dynamic environments offer the possibility for corrective actions, in contrast to static environments, it was predicted that cognitive performance would be worse in a dynamic task, on the assumption that people want to make accurate decisions with minimal mental effort. Furthermore, as it was assumed that the advantages of dynamic environments would reduce as time pressure increased, we predicted that both outcomes and cognitive performance would be more equal in dynamic and static tasks as time pressure increased.
In an experiment two versions of a similar diagnosis task were used: a static and a dynamic one. In the dynamic task version subjects decided in real time, and they saw a graph on a computer screen indicating the state of the system. In the static task version, subjects did not get this information and their task was to make one diagnosis per trial.
The results show that outcome performance was higher in the dynamic than in the static task version. Cognitive performance was worse in the dynamic task version as compared with the static one: subjects worked at a slower rate and they integrated the information less well. Outcome performance was equal for the dynamic and the static task version under a high level of time pressure. Cognitive performance improved under time pressure: subjects speeded up information processing and integrated the information more accurately.

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